# OHIO RIVER BASIN PRECIPITATION FREQUENCY STUDY

Update of *Technical Paper No. 40, NWS HYDRO-35* and *Technical Paper No. 49*

Seventh Progress Report
1 April 2001 through 30 June 2001

Hydrometeorological Design Studies Center
Hydrology Laboratory

Office of Hydrologic Development
U.S. National Weather Service
Silver Spring, Maryland

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DISCLAIMER

The data and information presented in this report should be considered as preliminary and are provided only to demonstrate current progress on the various technical tasks associated with this project. Values presented herein are NOT intended for any other use beyond the scope of this progress report. Anyone using any data or information presented in this report for any purpose other than for what it was intended does so at their own risk.

## Acknowledgments

Meteorologists, statisticians, computer experts and support staff have contributed to the Ohio River Basin Precipitation Frequency Study. This includes, but is not limited to, the following people:

Douglas Fenn, Meteorologist
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## 1. Introduction.

The Hydrometeorological Design Studies Center (HDSC), Hydrology Laboratory, Office of Hydrologic Development, U.S. National Weather Service is updating its precipitation frequency analysis for the Ohio River Basin. Current precipitation frequency studies for the Ohio River Valley are contained in *Technical Paper No. 40* "Rainfall frequency atlas of the United States for durations from 30 minutes to 24 hours and return periods from 1 to 100 years" (Hershfield 1961), *NWS HYDRO-35* "Five- to 60-minute precipitation frequency for the eastern and central United States" (Frederick et al 1977), and *Technical Paper No. 49* "Two- to ten-day precipitation for return periods of 2 to 100 years in the contiguous United States" (Miller et al 1964). The current study includes collecting data and performing quality control, compiling and formatting datasets for analyses, selecting applicable frequency distributions and fitting techniques, analyzing data, mapping and preparing reports and other documentation.

The study will determine annual and seasonal precipitation frequencies for durations from 5 minutes to 60 days, for return periods from 2 to 1000 years. The study will review and process all available rainfall data for the Ohio River Basin study area and use accepted statistical methods. The study results will be published as a Volume of NOAA Atlas 14. They will also be made available on the internet using web pages with the additional ability to download digital files.

The study area covers 13 states completely and parts of nine additional bordering states (Figure 1). The Susquehanna River and Delaware River Basins are included in the study area. The core and border states, as well as regions used in the analysis, are shown in Figure 1.

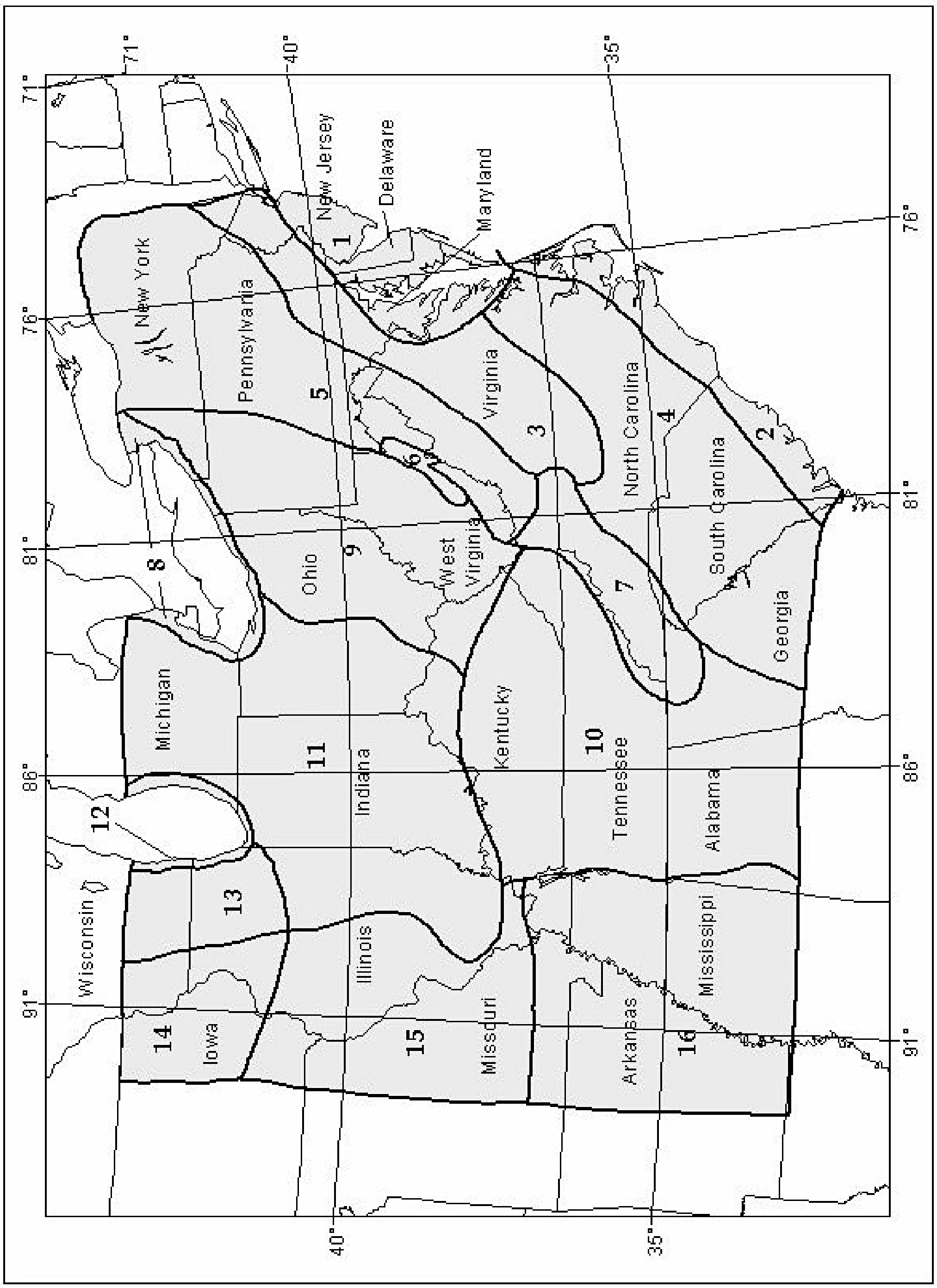


Figure 1. Ohio River Basin Precipitation Frequency study area and region boundaries.

## 2. Highlights.

Due to a software malfunction, 294 daily stations had been omitted from the analysis. These 294 daily stations, primarily in Regions 9, 10 and 11 (i.e., Illinois, Indiana, Kentucky, Ohio, Tennessee, and West Virginia), have been evaluated and are now included in the precipitation frequency calculations. Discordancy checks were done for the 294 additional stations. Thus, the quality control for the daily dataset for the Ohio River Basin is complete through November 1998. Data through December 2000 are currently being quality controlled and added. Additional information is provided in section 4.1, Update of Data Collection and Quality Control.

Evaluation of the spatial seasonal patterns of extreme precipitation has begun, and 12 experimental monthly percentage grid maps have been created. Some generalized spatial patterns and monthly differences are evident in the percentage grid maps. Final seasonality conclusions will be developed from these maps. Additional information is provided in section 4.2, Update of Seasonality.

The National Weather Service headquarters has reorganized, and the new management has initiated review of the Hydrometeorological Design Studies Center. Additional information is provided in section 5.1, Organizational Review by New Management.

## 3. Status.

### 3.1 Project Task List.

The following checklist shows the components of each task and an estimate of the percentage completed per task. Past status reports should also be referenced for additional information.

Ohio River Basin study checklist [estimated percent complete]:

Data Collection, Formatting and Quality Control [90%]:

- Daily
- Hourly
- N-minute

L-Moment Analysis/Frequency Distribution for 1 hr - 60 days and 2 to 1000 yrs [90%]:

- Daily
- Hourly
- N-minute

Algorithm/Data Plot [15%]

- Establish regions from spatial, topographic and meteorological variables
- Run L-moments for regional growth factors to generate dataset
- Create 2yr-24hr precipitation frequency index map
    - Format dataset
    - Review maps (i.e., station id's, discordancy, elevation, frequency values)
    - Review hand-drawn analysis
    - Perform digitization
    - Rasterization
    - Generate contour rasters for final map
- Create ratio maps - 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr
    - Plotting
    - Review hand-drawn analysis
    - Perform digitization
    - Rasterization
- Create regional growth factor maps - 2yr (1-12) hr/2yr 24hr, 2yr (2-60) day/2yr 24hr

Precipitation Frequency Maps [10%]

- Create frequency maps for 1-hour to 60-day durations at return periods 2 to 1000 years (seasonal and annual maximum) by multiplying index map rasters and using appropriate regional growth factor and ratio map rasters
- Create maps and/or relations for durations smaller than 1 hour (5, 10, 15, 30 minute) using index map and appropriate conversion factors
- Perform internal consistency checks (comparing rasters of sequential duration and frequency)

Temporal Distributions of Extreme Rainfall [0%]

- hourly data assembled by quartile of greatest precipitation amount and converted to cumulative rainfall amounts for each region
- graphs of representative storm-types and seasons

Spatial Relations (Depth-Area-Duration Studies) [0%]

- analyze critical storms to determine depth-area-duration relations
- small-area, short-duration relations
- area-depth curves for areas <500 $mi^2$ and for >500$mi^2$
- families of mass curves and area-depth curves as a function of duration and area size
- a smoothed set of curves to distinguish between convective, tropical and non-tropical storms (if appropriate)

Deliverables [5%]

- Write hard copy of Final Report
    - Maps of analyzed results
    - Graphical relations to obtain intermediate values
    - Seasonal variation
    - Depth-area distribution
    - Temporal distribution of rainfall in extreme storms
    - Implement peer review
- Prepare data for web delivery
- Prepare documentation for web delivery
- Publish hard copy of Final Report

### 3.1.1 Data Collection and Quality Control.

The daily, hourly and n-minute datasets have been updated through November 1998. We are in the process of adding data to these stations through December 2000.

Table 1. Information on daily, hourly and n-minute datasets through November 1998. Information includes the 294 daily stations mentioned earlier.

| | **Daily** | **Hourly** | **N-minute** |
|---|---|---|---|
| **No. of stations** | 3269 | 984 | 76 |
| **Longest record length (yrs)**<br>**(Station ID)** | 119<br>(20-0230) | 99<br>(36-6993) | 26<br>(44-8906) |
| **Average record length (yrs)** | 56 | 42 | 24 |

### 3.1.2 Statistical Analysis.

Frequency Distribution Fitting Analyses:

This task evaluates and selects the frequency distribution which provides the best fit for the data. A comprehensive L-moment statistical analysis (Hosking and Wallis 1997) of goodness-of-fit has been done on both daily and hourly data through November 1998 for all durations and all regions to select a best-fit distribution. The statistical analysis included the previously omitted 294 daily data stations. The best-fit for the partial duration (PD) in this project is the Generalized Normal distribution (GNO) for precipitation frequency estimates.

Trend and Shift Statistical Analysis:

As part of the data quality control for the Ohio River Basin study, trend and shift analyses were performed on the annual maximum (AM) precipitation data. A total of 2755 stations in 22 states were examined. As reported in the Sixth Progress Report, the AM precipitation time series data were found generally free from linear trends and free from shifts in the mean for most stations in the Ohio River Basin at a 90% confidence level. Specifically, 1510 (or 84%) of 1797 tested stations are free from linear trends, and 437 (or 82%) of 531 tested stations are free from shifts in the mean. The trends and shifts were significant in approximately 15% of the stations (Lin and Julian 2001). More than 50%, or 229, of 417 tested stations with data lengths of 80 years or longer show a significant increase in the variance. The average increase in the standard deviation for the 229 stations with a significant increase is 23% in the recent four decades in comparison to the earlier four to six decades. The results suggest that the AM time series in the Ohio River Basin varied statistically in a wider range between the extreme highs and the extreme lows in the recent four decades than in the earlier four to six decades.

A key assumption of the statistical approach to precipitation frequency analysis is that the climate in the time period of the analysis is representative of the climate for the life of designs based on the analysis. While the trend analysis has identified some changes, it is not clear whether or how these changes will continue. Therefore we will continue to assume that the statistics of the period of data used in the analysis are sufficient for this study.

After completion of the trend and shift analysis, data quality control was performed on stations exhibiting a significantly high linear trend and/or shift in the AM time series data. Suspicious data were examined, but no need for corrections was found.

3.1.3 Mapping Analyses.

HDSC continues to explore the possibility of using spatial interpolation tools such as the Parameter-elevation Regressions on Independent Slopes Model (PRISM). Discussions with the Spatial Climate Analysis Center will determine if there are ways to overcome possible technical and legal issues which present a barrier to use of PRISM technology.

3.1.4 Documentation and Publication.

The Ohio River Basin study results will be available on the HDSC Precipitation Frequency Data Server (PFDS), formerly the Graphical User Interface (GUI), once mapping is complete. The PFDS displays precipitation frequency values and intensity-duration-frequency curves and tables. At present, all states can be selected. Where studies are not yet concluded, information on existing precipitation frequency maps, namely TP40 (Hershfield 1961) and NOAA Atlas 2 (Miller et al 1973), is given.

## 4. Progress in this Reporting Period.

### 4.1 Update of Data Collection and Quality Control.

Due to a software malfunction, 294 daily stations had been omitted from the analysis. These 294 daily stations, primarily in Regions 9, 10 and 11 (i.e., Illinois, Indiana, Kentucky, Ohio, Tennessee, and West Virginia), have been evaluated and are now included in the precipitation frequency calculations. Discordancy checks were done for the 294 additional stations. Thus, the quality control for the daily dataset for the Ohio River Basin through November 1998 is complete. We are in the process of adding data through December 2000.

Table 2. Daily stations with ≥ 20 data years (data through November 1998 and including additional 294 stations).

| Region | No. stations with ≥ 20 data years |
|---|---|
| 1 | 125 |
| 2 | 45 |
| 3 | 206 |
| 4 | 224 |
| 5 | 440 |
| 6 | 10 |
| 7 | 178 |
| 8 | 35 |
| 9 | 375 |
| 10 | 512 |
| 11 | 421 |
| 12 | 35 |
| 13 | 77 |
| 14 | 94 |
| 15 | 215 |
| 16 | 277 |
| Total | 3269 |

Table 3. Hourly stations with ≥ 20 data years (data through November 1998).

| Region | No. stations with ≥ 20 data years |
|---|---|
| 1 | 25 |
| 2 | 11 |
| 3 | 54 |
| 4 | 54 |
| 5 | 148 |
| 6 | 3 |
| 7 | 35 |
| 8 | 11 |
| 9 | 137 |
| 10 | 112 |
| 11 | 173 |
| 12 | 18 |
| 13 | 17 |
| 14 | 36 |
| 15 | 70 |
| 16 | 80 |
| Total | 984 |

The n-minute (i.e., 5-minute, 10-minute, 15-minute, 30-minute) data collection, formatting process and quality control is complete through December 1997 for all 16 regions in the Ohio River Basin study area. We are not aware of n-minute data available after December 1997.

Table 4. N-minute stations with ≥ 20 data years.

| Region | No. stations with ≥ 20 data years |
|---|---|
| 1 | 5 |
| 2 | 3 |
| 3 | 6 |
| 4 | 7 |
| 5 | 6 |
| 6 | 1 |
| 7 | 1 |
| 8 | 4 |
| 9 | 7 |
| 10 | 9 |
| 11 | 10 |
| 12 | 2 |
| 13 | 3 |
| 14 | 3 |
| 15 | 4 |
| 16 | 5 |
| Total | 76 |

The discordancy check for the Ohio River Basin daily data, including the additional 294 stations, has been completed for all 16 regions. The stations in which the discordancy value is equal to or greater than 5.0 were closely scrutinized for suspicious or unusual data. Methods to examine the suspicious data include, but are not limited to, comparing with other data sources (e.g., microfiche), comparing with hourly data and checking with other stations in the vicinity.

For example, three suspicious values were examined at a daily station in Region 9. The daily station had a discordancy value of 5.71, and the three data values were 8.02" on 11/02/1992, 7.25" on 12/04/1992 and 6.39" on 09/29/1992. A spatial check displayed no comparable rainfall amounts in the vicinity of the station for those dates. As a result, these three values were marked as missing.

In summary, these analyses show that the quality control for the daily dataset through November 1998 for the Ohio River Basin has been thoroughly executed.

4.2 Update of Seasonality.

In order to best evaluate the spatial seasonal patterns of extreme precipitation 12 monthly percentage grid maps have been created. The value plotted is the percentage of annual maximum events occurring in a given month for a station. It equals the number of times the annual maximum occurred in that month divided by the number of total annual maximum events occurring for that station, multiplied by 100.

For a given station:

% an. max. events in January = (# of an. max. in January/ # total an. max. events) * 100

For example:

10% of an. max. events occurred in January = (5 an. max events in January/ 50 an. max. events) * 100

Thus for a station with 60 years of record, 60 annual maximum values exist. If 10 annual maximum events occurred in January, and 5 occurred in February then the values plotted would be 16.7% (i.e., (10/60)*100) and 8.3% (i.e., (5/60)*100).

For initial evaluation, these percentages were mapped and spatially interpolated to a grid for each month using a simple inverse-distance-weighting (IDW) technique. Fifteen minute by fifteen minute grid cells were used in order to discern general patterns and eliminate noise in the data.

Rainfall seasonality needs to be further evaluated for seasonal and/or monthly patterns (e.g., convective, hurricane). Some generalized spatial patterns and monthly differences are evident in the percentage grid maps. For instance, a concentration of relatively high percentages can be found along the Atlantic coast during peak hurricane season (i.e., August and September). Figure 2 shows the percentage of annual maximums occurring in August. Final seasonality conclusions will be developed from these maps.

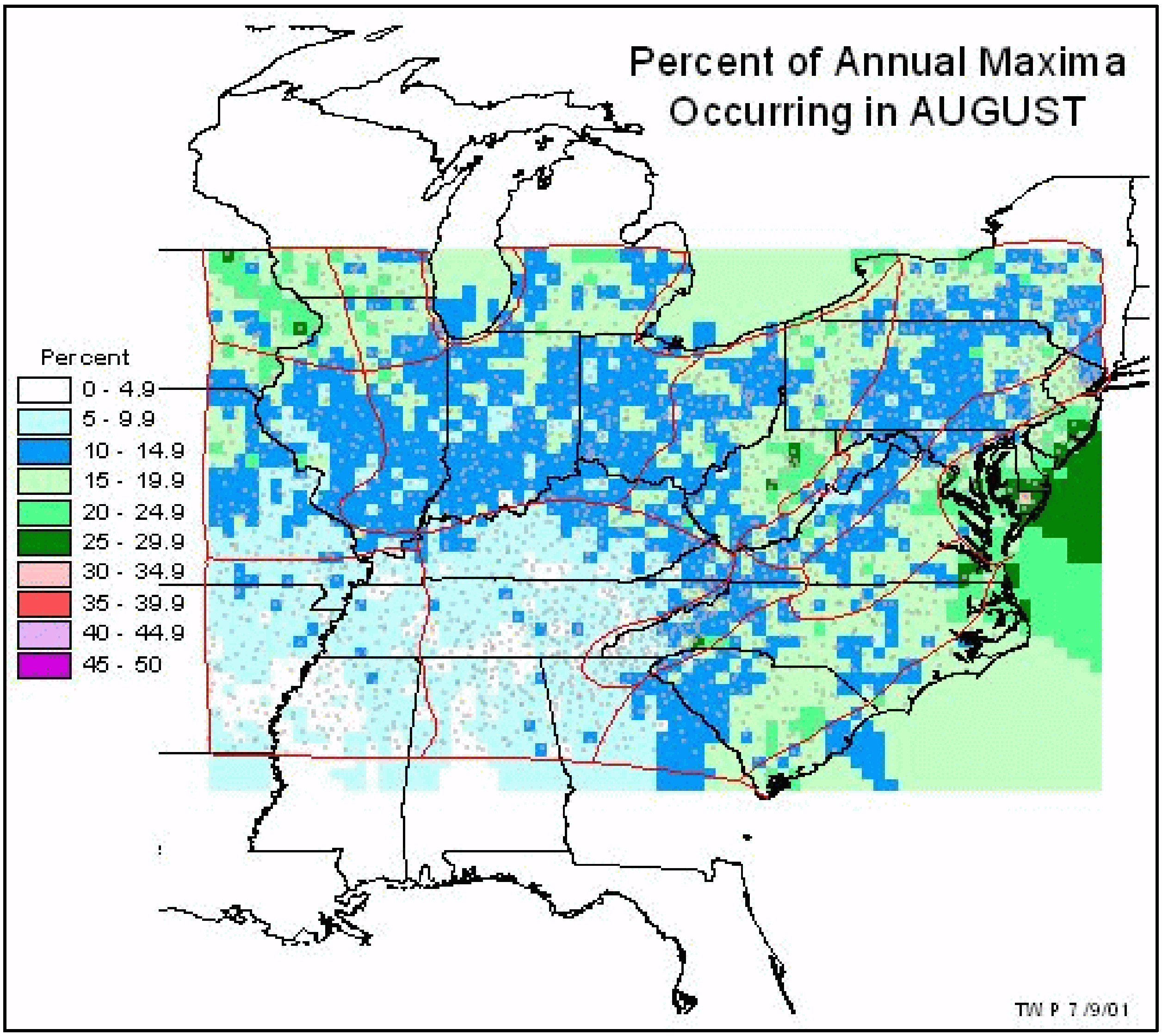


Figure 2. Seasonality map for August.

## 5. Issues.

### 5.1 Organizational Review by New Management.

The National Weather Service headquarters has reorganized (details can be viewed at http://www.nws.noaa.gov/oh/start.html). The new management has initiated review of the Hydrometeorological Design Studies Center.

#### 5.1.1 Technology

A committee of technical experts from our partners is reviewing the technology we are using for precipitation frequency analysis. The committee members are:

Rocky Durrans, The University of Alabama, Tuscaloosa, AL (Rapporteur)
Greg Johnson, USDA-NRCS National Water and Climate Center, Portland, OR
Lou Schreiner, U.S. Bureau of Reclamation, Lakewood, CO
Jim Angel, Illinois State Water Survey, Champaign, IL (representing the American Association of State Climatologists)
Art DeGaetano, Northeast Regional Climate Center, Ithaca, NY
Will Thomas, Michael Baker Corporation, Alexandria, VA (representing the Transportation Research Board)
David Goldman, U.S. Army Corps of Engineers, Davis, California
Geoff Bonnin, NWS Office of Hydrologic Development, Silver Spring, MD (Chairman)

The committee is looking at:

1. Data Collection and Quality Control: The committee suggested NWS contract for the data collection and quality control work. To that end, the Northeast Regional Climate Center has submitted a proposal combining the expertise of each of the regional climate centers. Since the data collection and quality control work for the Ohio River Basin Precipitation Frequency Study is almost complete, there will be no impact on this study.

2. Statistical Analysis Procedure: The committee recommended a panel of recognized experts review the procedures. The NWS is currently responding to the first round of review comments. The NWS expects the statistical analysis procedures to be validated with perhaps minor adjustments. We do not expect any impact on the Ohio River Basin Precipitation Frequency Study.

3. Spatial Interpolation: The committee recommended discussions with the Spatial Climate Analysis Center to determine if there are ways to overcome possible technical

and legal issues which present a barrier to use of PRISM technology. PRISM-like technologies may offer benefits in the area of productivity, however evidence to date has raised questions about interpolation quality. We continue to follow developments in this area and will adapt our approach if appropriate.

5.1.2 Funding and Schedule

The technical committee recommended that precipitation frequencies for the entire United States be updated within three years. While the management review is not yet final there is a significant concern about whether the funds available are consistent with these expectations and whether current schedules are realistic.

## 6. Projected Schedule.

The following list provides a tentative schedule with completion dates. Brief descriptions of tasks being worked on in the next quarter are also included in this section.

Data Collection and Quality Control [August 2001]
L-Moment Analysis/Frequency Distribution [October 2001]
Algorithm/Data Plot [November 2001]
Precipitation Frequency Maps [December 2001]
Temporal Distributions of Extreme Rainfall [February 2002]
Spatial Relations (Depth-Area-Duration Studies) [February 2002]
Implement Precipitation Frequency Data Server (PFDS) [February 2002]
Write hard copy of Final Report [March 2002]
Implement review by peers [April 2002]
Publish hard copy of Final Report [June 2002]

6.1 Data Collection and Quality Control.

Daily and hourly station data up through December 2000 will be added to the dataset and included in the precipitation frequency calculations. The tasks involved with data collection, formatting and quality control will take roughly one month for all 16 regions in the Ohio River Basin study area. We are not aware of n-minute data available after December 1997. The current dataset contains station data from the National Climatic Data Center (NCDC), the U.S. Army Corps of Engineers (COE), the Tennessee Valley Authority (TVA) and the U.S. Geological Survey (USGS).

6.2 L-Moment Analysis/Frequency Distribution.

A comprehensive L-moment statistical analysis will be done on both daily and hourly data through December 2000 for all durations and all regions to select a best-fit distribution. The tasks involved with the statistical analysis will take roughly one month for all 16 regions in the Ohio River Basin study area.

6.3 Precipitation Frequency Maps.

A sophisticated cartographic-map making process has been designed using the latest GIS software, ArcView 8.1. During the next few months the review and revision process will result in a final cartographic-quality map template. This map template will then serve as the basis for all future precipitation frequency maps. The maps will be available both online (as postscript and JPEG files) and in a hardcopy form with the final reports.

6.4 Precipitation Frequency Data Server (PFDS).

Once the data and mapping are finalized, the precipitation frequency estimates for the Ohio River Basin study will be available from the newly developed HDSC web-based Precipitation Frequency Data Server (PFDS). The PFDS will display precipitation frequency values, as well as intensity-duration-frequency (IDF) curves and tables. Eventually, all states will be selectable from the opening U.S. map.

## References

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